Computer and Telecommunication Engineering (2023) Volume 1 Issue 1
doi: 10.54517/cte.v1i1.2266

REVIEW ARTICLE

The IRNSS/NavIC designing characteristics and development in antenna application: An overview

Anshu Gaur[*], Navneet Kumar Agrawal

Department of Electronics and Communication, CTAE, MPUAT, Udaipur, Rajasthan 313001, India

*** Corresponding author:** Anshu Gaur, anshugaur01@gmail.com

ABSTRACT

Today is a generation of the satellite navigation system and every country needs its own positioning and secured services. GPS invention has given birth to a new era in technology. India in terms of population is highly dense and should have its own navigation system. High-level research is still going on for Navigation with Indian Constellation (NavIC) the Indian Regional Navigation Satellite System (IRNSS) to be developed for the frequency band L-band (1176.45MHz) and S-band (2492.08 MHz). In this paper, we summarize the attributes characterizing the NavIC antenna which includes patch size, polarization, Fractal attributes, etc. Similarly, the paper gives technical inputs to develop a compact and efficient NavIC antenna system for future L-band and S-band.

Keywords: stack patch; dual band circularly polarized; axial ratio; bandwidth; gain

1. Introduction

The antenna is an essential component of navigation technology, in determining how effectively devices function. Therefore, careful consideration should be given to the antenna design for every Navigation technology device in order to ensure good system performance. Because of their low profile and simplicity of integration related to GNSS technology, antennas have drawn a lot of interest over the past few decades and are particularly well suited for usage in compact navigation technology devices.

GNSS provides much information regarding position, velocity, and timing, mapping, meteorological and atmospheric data, geographic surveys, monitoring, and public safety. With the help of an electronic receiver and constellation satellite (transmits the time signal); the user can locate the position (longitude, altitude, and latitude) of the desired place. Many countries have their navigation system like Global Positioning System for the USA, Global Navigation Satellite System (GLONASS) for Russia, and BeiDou Navigation Satellite System for China. There are some regional satellite systems which are in the developing phase like Quasi-Zenith Satellite System (QZSS) for Japan and IRNSS NavIC for India. The GPS is one of the GNSS systems with constellation of 24 MEO satellites and provides 7.1% accuracy in positioning with 95% assurance. The GLONASS with 7.5 m position accuracy, Galileo with 4m position accuracy, BeiDou with a 10m accuracy position[1].

A new system of regional navigation for India is IRNSS NavIC, whose operational name is NavIC

ARTICLE INFO
Received: 1 August 2023 | Accepted: 20 September 2023 | Available online: 6 October 2023

CITATION
Gaur A, Agrawal NK. The IRNSS/NavIC designing characteristics and development in antenna application: An overview. *Computer and Telecommunication Engineering* 2023; 1(1): 2266. doi: 10.54517/cte.v1i1.2266

which is a short form of Navigation using the Indian Constellation, which is an Indian word for “sailor”. Before IRNSS NavIC, India was depending on other countries for its navigation system. In 1999 Indian Military needed navigation satellite system for the Kargil region. The civilian user’s Positioning Services (SPS) and others are restricted services for specific uses. India’s Own Navigation system is according to its geographical structure shown in **Figure 1**. It has 7 satellites 3 in geostationary which are positioned at 131.5° East, 83° East and 32.5° East and 4 in geosynchronous orbits, each plane has two satellites that are positioned at 111.75° East and 29° to the equatorial plane, with longitude crossings of 55° East and 111.75° East. These satellites are visible for 24 hours in the Indian region and they are also providing accurate results for the 1500 km extended region boundary for India. It covers many sea routes, the Indian Ocean and a region lying between 30° south to 50° north Latitude and 30° east to 130° east. The accuracy of the system is 10 meters for the Indian land and 20 meters for the Indian Ocean. It transmits a signal on two bands for the L band it has L1 (1575.42) and L5 (1176.45 MHz) and the other band is S (2492.08MHz) band with standard positioning service (SPS). IRNSS system is expected to give 2-sigmaposition accuracy. Due to the restricted space and weight on board, the frequency of IRNSS presents a significant problem in antenna design[1,2]. Many proposed antennas by researchers are designed on different bands; some are for single band, dual band and hybrid antennas. The multiple band cover antennas are giving more accurate result which is also reviewed in this paper.

For the Navigation antenna, the circular polarization is the main component. In this paper, many proposed antennas by researchers achieved circular polarization and some are on linear polarization. The axial ratio of the antenna defines the polarization of the antenna; if it is below 3dB then it comes under the circular polarization. To maintain a 3dB axial ratio many techniques were reviewed in the paper. The shape and size of the antenna are crucial for GNSS. Today mobile is used by number of people in which the antenna should be small in size. So many new techniques were studied and used in GNSS antenna, one of them being Metamaterial. By introducing Metamaterial in GNSS the antenna reduced the size or improved the performance. There are a number of Metamaterial types like AMC, EBG, Double Negative etc. By using it we can enhance the antenna performance.

This paper discusses the design of the IRNSS NavIC antennas with an emphasis on how to accommodate all the technical attributes and bring out with optimum solution for all future NavIC systems. This review study surveys all of the significant and unique IRNSS NavIC antenna-related approaches that have been reported in the literature. By highlighting the benefits and drawbacks of each approach, this paper makes it simpler for students and professionals working in antenna design and other antenna-related fields to select the approach that is best suited for the given application. Additionally, we highlight a few crucial factors that should be taken into account when solving antenna design issues for the IRNSS NavIC antenna.

The structure of this paper is as given below, the paper is divided on the basis of IRNSS/NavIC available bands i.e., single band, dual band and multi-band. The polarization technique provides an overview of the available literature on regarding IRNSS and GNSS. The several techniques used for a single-band, dual-band, circular position, and hybrid antenna reviewed in this paper.

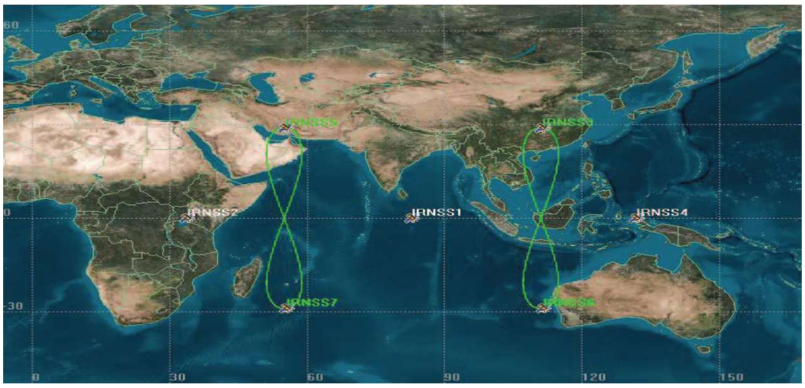


Figure 1. IRNSS constellation architecture.

2. Related work IRNSS antennas

Since quite a long time researchers are focusing on various combinations for designing of good NavIC systems. GPS has been used worldwide at one point at a time without any questions but now many countries have started their navigation system. Much literature work has been published on navigation systems but there is limited literature available for INRSS/NavIC. Designing an antenna for INRSS/NavIC purposes is needed to cover the following attributes.

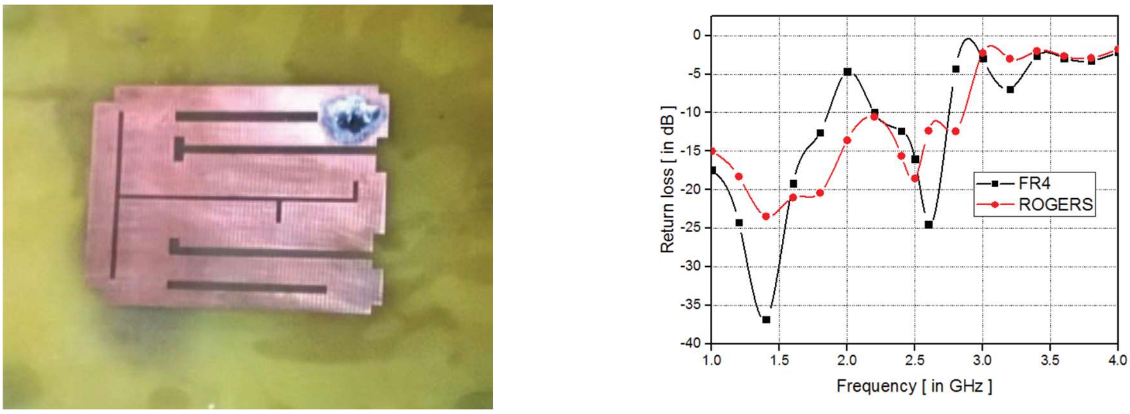
2.1. Microstrip slot for single and dual frequency band on the substrate

The three major operating frequencies are L1, L5, and S-Band for the GNSS system. The range for NavIC L5 band (1164.45–1188.45 MHz) with a center frequency of 1176.45 MHz and a bandwidth of 24 MHz, for S-band (2483.778–2500.278 MHz) with a center frequency 2492.028 MHz and the bandwidth of 16.5MHz. The L1 band has the center frequency of 1575.42 MHz. There are so many papers for single band, dual band frequencies which uses different techniques. Djebari et al. investigated a multiband antenna consisting of a rectangular patch with two shape slots. The two different H and U-shaped slots help to change the surface current of the patch[3]. In the paper different dimension effects of slots are explained and obtained three operation bands (1.06–1.233 GHz), (1.23–1.39 GHz), and (1.53–1.63 GHz) which are large enough to cover GNSS frequency. Raval designed patch antenna on IRNSS frequency 2.49GHz the gain and the directivity of the proposed antenna are 4.6 dB and 6.9 dB respectively. Microstrip patch antenna gives a return loss of −41 dB and bandwidth is 71.7MHz with VSWR around 1.01[4]. Sze and Wong implemented the proposed dimensions of the modified U-shaped slot. The comparison is done in the paper with different dimension of U-shaped slots. The result in lower and higher resonant modes obtain large bandwidth with 4.3 to 4.6%. The gain of the antenna is given 2.2 to 2.7 dB[5].

Pansuria et al. designed a single band microstrip patch antenna. The antenna resonates at a frequency of 1.176 GHz. The Zeonex RS420 substrate material is used. The feeding point was varied to get the minimum return loss of −38.6055 dB and the axial ratio of 1.3713 dB. The gain is 6.69 dB and obtains a satisfactory result for single-band operation[6]. Prajapati and Rawat designed compact and low-cost microstrip patch antenna for S-band applications of IRNSS receiver. The paper measured the result for the positioning error with Accord tri-band antenna L1, L5, and S-band and attitude error is least with GPS antenna[7].

The dual-band is a better choice for any navigation satellite system because of the effect of the ionosphere on frequency signals. Due to this the dispersive characteristics of the ionosphere, caused the frequency-dependent phase shift in the frequency. This problem can be solved by the dual frequency and it also offers many other advantages like redundancy and increased resistance to jamming. Shaw et al. present a compact antenna for L5 and S-band. The RF PIN diode is used in a design. The antenna is between the radiation element and the resonance slot. When the wind is on state its resonance frequency is 1.176GHz and in off states, it's 2.5 GHz. The patch length is varying and due to this inductance of geometry changes. The −30 dB is a cross-polarization level[8].

Lenin et al. designed an E shape microstrip antenna of substrate size 100mm × 100mm. In this paper author designed a different design of an E shape and improved the return loss and size of the slot at GPS and IRNSS frequency. At radiating frequencies 1.6 GHz and 2.57 GHz and 6dB and 7.25 dB gain respectively. The Author uses different substrates FR4 and Rogor and compares them shown in **Figure 2**[9]. Hussein et al. designed a microstrip patch antenna with a two-port transmitter and a receiver. The duplex antenna consists of a gear-shaped patch. The transmitter and receiver ports isolation is achieved by the frequency space filtering technique. In this technique to omega-shaped DGS (defected ground structure) and BPF (based band pass filter) are created. This isolation is high and larger than −36 dB at transmitting frequency f_t= 33GHz and larger than −45 dB at receiver frequency f_r = 3.125GHz. The antenna can cover S-band (2–4 GHz)[10]. Danhet al. designed a double ring in the middle of a rectangular microstrip patch. The small ring shape is cut in the middle of a patch by which get design resonates at a given frequency. The antenna Gain at the L5 band is 7.87 dB and at the S-band is 7.9 dB. The VSWR for the L5 band and the S-band is 1.3 and 2.1 respectively. The L5 is circularly polarized with an axial ratio is 2.6 dB. The antenna is in a single-layer structure and works for dual-band frequencies[11].



(a) **(b)**

Figure 2. (a) E shaped dual band antenna[9]; **(b)**comparative return loss for different substrates[9].

2.2. Circularly polarized radiation

Circular polarization is gaining the attention of researchers because of its importance in wireless communication. The purity of circular polarization is measured by cross-polarization. There are several techniques used for that like single feed configuration, double feed and multiple feed configuration is explained[12–17]. A dual circular polarization approach is used in the antenna for the right- and left-handed circular polarizations[18–23].

Vasanthan et al. designed corner truncated (RHCP) used in patch antenna for three different frequency bands[12]. Chandran et al. designed a dual-band stack antenna for the IRNSS receiver. The two bands L5 and S-band are the operating frequency of the antenna. By using a multi-layer structure the author achieves the dual frequency that two different substrates with the same height are used. The square notched cut at the diagonal of the patch is used for circular polarization. The fed location is selected as it produces a right-hand circular polarized pattern. The obtained results are good 50MHz for the L5 band (1.16–1.21GHz) and 90MHz for S-band (2.44–2.53 GHz). The gain is 1.02 dB and 6.73 for the L5 band and S-band respectively. The axial ratio is below 2 for both bands[13]. Lohar et al. presented the IRNSS receiver with circular polarization utilizing characteristics mode analysis (CMA) method. Three antennas have been designed and compared their results. The antenna was designed for S-band with 16.5 MHz bandwidth. Author determines the best feed point on the antenna for obtaining circular polarization for the excitation of two orthogonal modes by using characteristics mode analysis. By simply two cuts on diagonal of square radiating the patch, it obtains circular polarization and better results[14].

Khaleeq et al. discussed the circularly polarized corner truncated radiating patch designed using the coaxial feed mechanism. The antenna working frequency at 1.176 GHz and bandwidth of about 3.24%and 1.31 dB is axial ratio[15]. Mukherjee et al. developed IRNSS cost-effective antennas. The circular polarized was developed for IRNSS signal reception. The microstrip patch circularly polarized antenna resonating frequency 1176.45 MHZ with 28 MHz bandwidth. The corner truncated rectangular microstrip patch is used for right and circularly polarized behavior[16]. Birwal et al. proposed the broad impedance bandwidth and a wide slot using CPW feed in its antenna design. A rectangular patch is moved toward the left edge on ground surface. Besides, there is a square shape stubs left and right edge used on the ground plane. By this, the circular polarization is achieved at L1, L2, and L5. It provides the s_{11} parameter below −10 dB is 123% (1.1–4.72dB) and 18% of axial bandwidth from (1.5–1.8 GHz) and 11% (1.15–1.29 GHz) which has applications for GNSS and Wi-Fi[17]. Kranthi designed dual-band two patches stacked one above the other circular polarized antenna. In a circularly polarized antenna, the square technique is selected which is simplest. The antenna operates at L1 and L5. The Teflon fiber glass (TFG) is selected for an antenna. The upper patch and a bottom patch gets excited by electromagnetic coupling and fed by the connector respectively which is shown in **Figure 3**[18].

Singh et al. designed a circularly polarized antenna for S-band. It is a rectangular microstrip antenna with the diagonal corners modified. The antenna is compact as well as provides good results the axial ratio from (2.449–2.573GHz) is 3 which is 31MHz axial bandwidth. The antenna gain is 2.83 dB[19]. Pourbagher et al. designed and simulated a crossed antenna for resonance frequency 1.575 GPS. The use of different feeding techniques and ground plane achieved right-hand circular polarization. The 5.8 dBi measured RHCP gain and efficiency is 84%[20]. Reddy et al. designed a dual circular polarized antenna for L5 and S bands. By the stack of two microstrip patch are used. There is a separation of the frequency band in a ratio of 2.1:1. The patches are fed by 4 quadrature pins. These pins are at 2 adjacent axes. For achieving circular polarization 90-degree hybrid coupler is of for pins in amplitude and phase relationship used. The bandwidth is 26.3% and 24.8% for the L band S-band. The axial ratio is below 3 dB for both bands[21]. Patel et al. designed a dual-band circularly polarized L5 and S band antenna. By using the stacking technique on the substrate and putting an air gap between two substrates. The square notches and corner truncation is used at the diagonal of both the lower and upper patch. By this circular polarization is achieved. The bandwidth 50 MHz on the L5 band is and S-band having around 110 MHz and the bore sight side gain is 8.5dB and 7.03 dB respectively. The axial ratio bandwidth is 20 MHz megahertz for L5 and 80MHz for S-band. The VSWR is 1.61 for L5 and 1.19 for S-band[22]. Shukla et al. used single-fed stack technique for circular polarization. By using corner truncation technique of the square patch by which right-hand circular polarization is achieved. The stub and corner truncation are used for resonating the frequency and axial ratio[23].

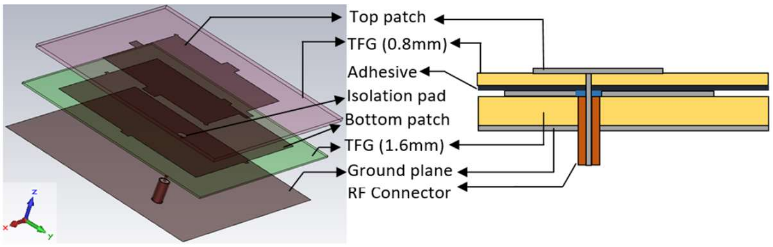


Figure 3. Configuration of antenna for circular polarization[18].

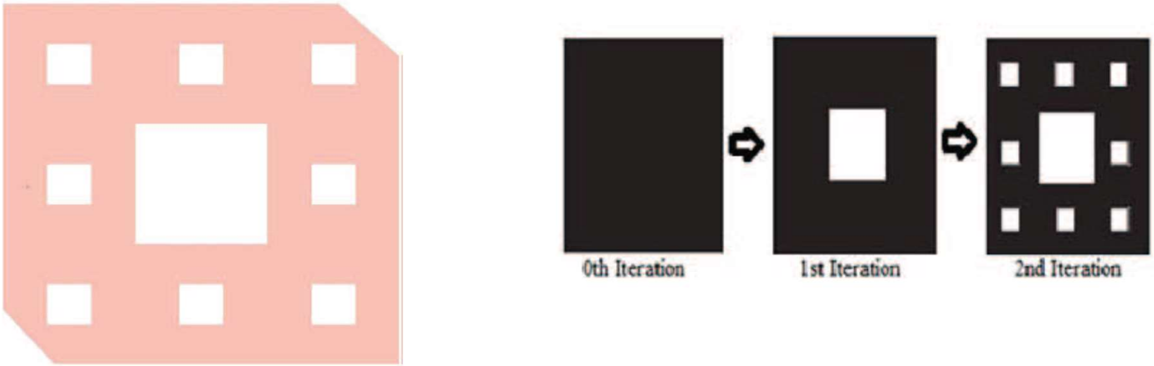
2.3. Tri-band or multiband resonant frequencies

Zhang et al. proposed an antenna with inverted F used across a double layer of the substrate; it will result in a low profile, tri-band with compactness in the antenna with reduced height for GNSS application. The antenna is composed of four inverted F antenna which is QIFA. In QIFA the quadrature-phase and amplitude are equal for the wide circular polarized range[24]. Waqas et al. studied the Sierpinski gasket based on a monopole antenna constructed up to three iterations. By self-similarity property of the Sierpinski fractal achieves multiband operation[25]. Srivatsun et al. presented a low-profile antenna with fractal geometry that is used in it[26,27]. A compact and low-profile multiband antenna designed at 2.4 GHz shows characteristics of WLAN, PCS, etc. The gain of the antenna is 11.5931dBi at 9 GHz, −9.437dBi at 1.075GHZ, and 8.25dBi at 1.25 GHz.

2.4. Fractal attributes of an antenna

Anagnostou et al. presented a frequency fractal antenna on frequencies bands (0–2 GHz) (0.4 GHz, 0.5 GHz, 0.8 GHz, 0.9 GHz, 1.5 GHZ, and 1.8 GHz) with one antenna active by switches according to the application[28]. Manimegalai et al. presented the multi-fractal concept in cantor antenna design covering GSM, DCS, PCS, etc. By the design, it is easy to control resonance and bandwidth. There are up to four design iterations for the whole Cantor fractal antenna. The result shows the multiband operation is done with a single-layer substrate[29]. Kathick and Kaashwar proposed the design of rectangular fractal antenna that used IRNSS and designed the concept of smart city application in India. IRNSS has a significant impact on India’s smart city in many applications like traffic congestion, disaster management, traffic control and smart transportation. The antenna is based on Sieroinski carpet antenna geometry. The dual band for IRNSS frequencies at 2492.08 MHz S band and 1176.45 MHz L band at return loss −24.323 dB and −13.41 dB respectively shown in **Figure 4**[30].

Some papers are on spiral antenna which shows great results. Sada Siva Rao et al. proposed a spiral antenna using RT DUROID substrate operating frequency 1.2 to 1.6 GHz and working for the frequency L5 1175 MHz. The four spiral elements are used for broadband satellite coverage. The array of spiral antenna is used for increased gain, reduction in size. The design includes interference suppression in combination with the space-time adaptive processor (STAP)[31]. Patel et al. presented a review on a spiral antenna in which reveals the type of spiral antenna and design principle of the antenna. The paper touches on various design ideas for the spiral antenna. For GNSS applications, the gain of spiral antenna may be improved by constructing an array, enhancing axial ratio and performance, and lowering arm length. Design strategy: dual-band, tri-band various design techniques explained[32].



(a) **(b)**

Figure 4. (a) Sierpinski fractal patches antenna design[30]; **(b)**Sierpinski carpet fractal antenna with iterations[30].

2.5. Metasurface inspired GNSS antenna

Recently Metamaterials have evolved as artificial materials. The help of metasurface also allows for the expansion of bandwidth and contributes to making the antenna smaller. Bouselmi et al. designed an antenna which is the quad-band antenna. In the paper, the author selects the L-shaped and rectangular patch on the FR4 substrate. By this, the ground plane's size is decreased and achieved the frequency Galileo, WLAN, WIMAX and radar application. For further improvement, the concept of AMC artificial magnetic conductor is used as a reflector. In paper, AMC is a metal surface with two rings where the inner ring for lower frequency and the outer ring provide the rest of the resonance frequency. The distance between AMC and antenna is so that it avoids mutual coupling and also keeps it as thin as possible. The AMC metasurface increases the gain more than 4dB in all frequencies, and helps antenna to work more efficiently[33]. Xuat et al. designed an antenna which is a single feed and using a metasurface of the square patch which is 4 × 4 arranged on a substrate. The antenna is for GPS application. There is a square patch on another side of the substrate with a truncated corner to produce circular polarization. The bandwidth is 1.562–1.733 (171 MHz), 3dB AR bandwidth 1.570–1.592 GHz (22 MHz)[34].

Gamer et al. proposed an antenna with miniature size and covers (Galileo, GLONASS and GPS). These two stacked patches with a cavity. The stacked patches are used to increase the bandwidth. The center frequency 1.578 GHz. The metasurface of the rectangular patch designs. The Author compared some results of the paper and concluded that the aperture reduction is 72%. The author proposed two compact metasurface antennas with center frequency 1.578 MHz. The small square metallic cavity is used. The linear polarization design is explained and then it has been extended to circular polarization by introducing double layer rectangular strip loading by two arrays 3 × 3 capacitive coupled square patches. Four feed ports are used to excite these square patches. The three bands are achieved with active gain 16 dB[35]. Liu et al. designed a low-profile antenna with circularly polarized using metasurface. The metasurface having a square metallic array and is excited with a microstrip line with the help of four cross slots. The antenna has the bandwidth of 17% and 14.5% AR bandwidth[36].

Ali and Biradar proposed three metasurface unit cells are designed in it. The objective of the paper observed the maximum range of negative permeability and negative permittivity. The final design has two complementing split-ring resonators and by which a narrower frequency range is achieved. The bandwidth is used in WLAN, WIMAX, Wi-Fi, and ITU bands[37]. Li et al. designed the double-sided metasurface for a circular slotted patch antenna and operating range 1.160–1.640 GHz in terms of S11 parameter below −10 dB. The gain is 3.99 dBic of the antenna which is RHCP[38]. Sumi proposed the dual-band circular polarization, dual rectangular loop antenna for GNSS. The operating frequencies are L1 and L2. The loop type is frequency selective. The surface is used to lower the height and increase the efficiency of the antenna. The axial ratio is L1 and L2 are 12.9% and 5.2% respectively shown in **Figure 5**[39]. Gaur et al. using the EBG structure which is used for the reeducation in mutual coupling[40].The hybrid phase shifter is introduced for the antenna with the good bandwidth[41]. The multiple band is achieves with the good gain and bandwidth by designing the coplanar waveguide[42].

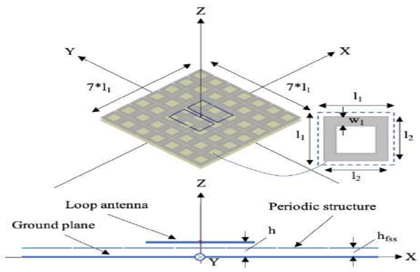


Figure 5. Antenna with metamaterial[39].

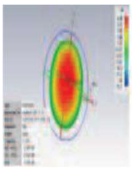
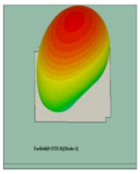
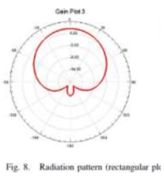
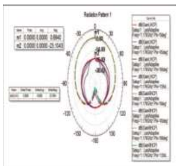
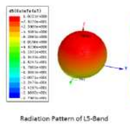
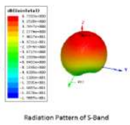
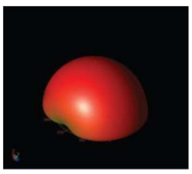
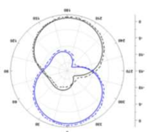
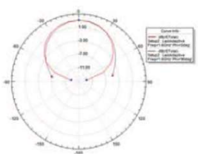
3. Summary and characteristics of antenna techniques

The various techniques for GNSS and IRNSS NavIC addressed in this paper are summarized in **Table 1**. The table lists the characteristics of each technique, considering gain, size, substrate, axial ratio, and other factors. The table shows that practically all of the strategies discussed above have a positive impact on the development of GNSS and IRNSS NavIC. The techniques, usedlike corner truncation with the different shape, corner truncation with different substrate, spiral antenna, stacks patch antenna, etc., compare clearly in the **Table1**. The Truncation cut is used in many antenna and come up with the circular polarization result. The spiral antenna compare with the other antennas reported with the high gain. The axial ratio is also important parameter for the GNSS antenna and for that many techniques is explained and can be seen in table also. Additionally, the antenna diameters have been adjusted such that they correspond to an antenna on a different substrate that covers the relevant single band, dual band, and multi-band frequencies. The bandwidths of small-size antennas are extremely constrained, but the miniaturization factors of wider-bandwidth antennas are lower. Low radiation efficiency is a problem for smaller antennas as well, especially when compactness is an issue.

Table 1. Comparative study of technical attributes of antenna.

Parameter	**1**	**2**	**3**	**4**	**5**	
	Microstrip patch	**Corner Truncated Microstrip SQUAR Ear Patch Antenna**	**Microstrip Rectangular Patch Antenna MODEL 1**	**Corner Truncated Microstrip rectangular Patch Antenna**	**Corner Truncated Microstrip Square Patch Antenna**	
Frequency band (GHz)	1.176	2.493 GHz	1.176GHz	1.176 GHz	1.17645 GHz	2.4920 GHz
Band	L band	S band	L band	L band	L band	S band
Substrate type	FR-4	FR4 Epoxy	Zeonex RS420	RT duroid 6006	RT/Duriod 5880 (upper patch)	FR4 Epoxy (lower patch)
Dielectric constant	4.1	4.3	2.3	6.15	2.2	4.4
Length of patch (L)	60.64mm	28	81.7mm	80	100 mm	
Width of patch (W)	77.2mm	28	82.7mm	80	100mm	
Substrate height (h)	0.035mm	1.6mm	1.6mm	2.54 mm	4.75mm	

Table 1. (*Continued*).

Parameter	**1**	**2**	**3**	**4**	**5**	
	Microstrip patch	**Corner Truncated Microstrip SQUAR Ear Patch Antenna**	**Microstrip Rectangular Patch Antenna MODEL 1**	**Corner Truncated Microstrip rectangular Patch Antenna**	**Corner Truncated Microstrip Square Patch Antenna**	
Directivity	NA	NA	4.4832	NA	NA	
Gain	3.83 dB	3.05dB	6.49 dB	0.68 dB	1.02 dB	6.73 dB
Axial ratio	NA	0.08 dB	1.3713 dB	1.31 dB	below 2 dB	
Return loss (dB)	−17.5 dB	−16 dB	−38.60 dB	NA	NA	
−10 dB impedance BANDWIDTH	NA	130 MHz	NA	38 MHz	50 MHz	90 MHz
VSWR	NA	NA	1.0238	1.25	NA	
Radiation pattern						
Parameter	**6**		**7**	**8**	**9**	
	Multiband fractal antenna		**Spiral antenna**	**Triband microstrip antenna**	**E SHAPE**	
Frequency band (GHz)	1.175 GHz	2.492 GHz	1.175 GHz	1.12–4.72 GHz	1.6 GHZ	2.57 GHz
band	L and S band		L BAND	L band	L band	
Substrate type	FR4		RTDURIOD	FR4	FR4 substrate	
Dielectric constant	4.8		NA	4.4	4.4	
Length of patch (L)	57 mm		NA	55 mm	100 mm	
Width of patch (W)	54 mm		NA	55 mm	100 mm	
Substrate height (h)	3.05 mm		NA	1.5 mm	5 mm	
Gain	NA		9 dB	NA	7.25 dB	6 dB
Axial ratio	NA		NA	NA	NA	
Return loss (dB)	−24.323 dB		−13.41 dB	NA	−19.6 dB	−17 dB
−10 dB impedance BANDWIDTH	74 MHz		104 MHz	NA	NA	
VSWR	NA		NA	NA	1.93	2.41
Radiation pattern						

4. Design steps of proposed antenna

For Global Navigational Satellite System application selection should be based on the requirements with which the antenna will be used. The helix and patch antenna have always been in demand. For compact, less in weight, high gain, easy fabrication, patch antenna is the perfect choice. It can be easily fabricated on a

Flat surface. By using different substrates fabrication costs can be reduced like FR4 and Air as dielectric. In Microstrip antenna the Multilayer structure is one of the easiest and efficient ways to achieved multiple frequency operations. There are advantages to using multiple frequencies when it comes to accuracy, synchronization and coverage area. There are many research papers dealing with multiple frequencies. The proposed design has a multi layer square patch with dual-band L band and S band.

The circular polarization is a requirement for its 360-degree coverage with appropriate orientation which could be right-hand circular. Since the IRNSS satellites use the right-handed circular polarization to the transmit signals, using a linearly polarized antenna results in a 3 dB loss at the receiving end due to polarization mismatch. The circular polarization is preferable for any GNSS antenna. Circular polarization solves transmitter and receiver alignment problem. Many techniques are shown in the paper by which circular polarization can be achieved. The proposed antenna is using the stack patches and truncation cut to maintain the axial ratio below 3dB. The cost and size of the antenna is the main factor so many antennas with compact size and different substrate are used. There are many techniques reviewed for minimizing the size of antenna. Fabrication cost can also be reduced by using substrate materials with low permittivity and the proposed antenna uses substrate materials like FR-4 which is cost effective.

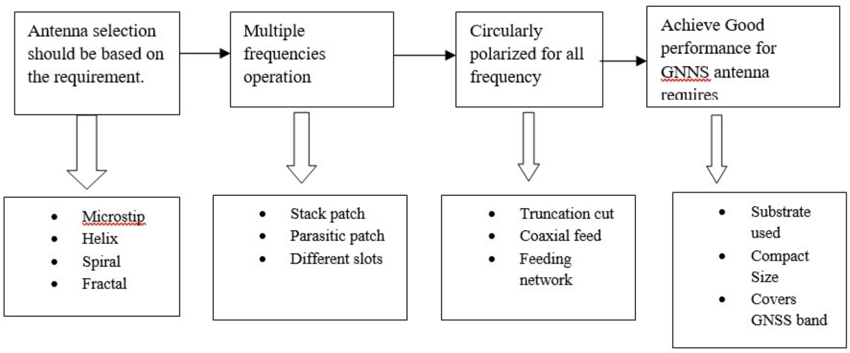


Figure 6. Steps for the proposed antenna.

Figure 6 shows a step for the proposed antenna which is summarized from the different research paper which is explained above in detail. These steps are the basic roadmap for a good GNSS antenna. With the help of above research papers; we utilized the advantages of different antenna for our proposed antenna. The antenna which is proposed from or research work should be compact in size due to which easy to use. The multiple bands should be covers so that the antenna performance is enhanced and give accurate results. The multiple bands should be circularly polarized so that the 3dB mismatching is not occurring and alignment problem is solved. Finally, antenna should be cost effective also so it can be used in many devices.

5. Conclusion

The comprehensive overview of NavIC is presented in this paper. The different types of design for GPS and NavIC have been studied in this paper. All design review along with their advantage and disadvantage have been summarized. Some paper shows the suitable design for NavIC. The metasurface is used in many GPS antennas and so it could be used in NavIC also. Some antenna shows great results on the frequency band L and S with high gain and directivity. Using the above design steps, the future NavIC antenna design would be compact in size with better directivity, high gain, and better efficiency.

Additionally, many of the methodologies that have been described so far offer little information for a general design process and don't discuss how the technique may be used to construct antennas for another band. Therefore, the issue needs to receive more focus in future efforts.

Author contributions

Conceptualization, AG and NKA; methodology, AG and NKA; formal analysis, AG and NKA; writing—original draft, AG and NKA; validation, NKA; writing—review and editing, NKA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

1. Morton YJ, van Diggelen F, Spilker JJ, et al. *Position, Navigation, and Timing Technologies in the 21st Century Integrated Satellite Navigation, Sensor Systems, and Civil Applications*. John Wiley & Sons; 2021. pp. 171–186.
2. ISRO Bulletin. The importance of the Indian ocean: Trade, security and norms. Available online: https://lki.lk/wp-content/uploads/2018/10/LKI_Explainer_The_Importance_of_the_Indian_Ocean_Trade_Security_and_Norms_Pabasara-Kannangara_Adam-Collins_and_Barana-Waidyatilake.pdf (accessed on 20 May 2019).
3. Djebari M, Abdelhadi A. Compact multi-band rectangular slotted antenna for Global Navigation Satellite Systems (GNSS). In: Proceedings of Electronics, Communications and Photonics Conference (SIECPC); 16–20 December 2012; Algiers, Algeria. pp.1–5.
4. Raval DH. Design of a Rectangular Microstrip Patch Antenna for Indian Regional Navigational Satellite System. *International Journal for Scientific Research & Development* 2015; 3(2): 316–317.
5. Sze JY, Wong KL. Slotted rectangular microstrip antenna for bandwidth enhancement. IEEE Transactions on Antennas and Propagation 2000; 48(8): 1149–1152. doi: 10.1109/8.884481
6. Pansuria B, Sharma S, Rawat A. Design of 1.176GHZ micro-strip patch antenna for IRNSS applications. In: Proceedings of the 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT); 10–12 July 2018; Bengaluru, India. pp. 1–4.
7. Prajapati M, Rawat A. Performance analysis of IRNSS using compact microstrip patch antenna for S band application. *Acta Geophysica* 2020; 68(4): 1223–1228. doi: 10.1007/s11600-020-00458-5
8. Shaw M, Choukiker YK. Frequency Reconfigurable Microstrip Patch Antenna for IRNSS Applications. In: 2020 International Conference on Inventive Computation Technologies (ICICT); 26–28 February 2020; Coimbatore, India. pp. 878–880. doi: 10.1109/ICICT48043.2020.9112476
9. Lenin GJN, Babu TG, Rajkumar R, Ramanathan A. Design of an E shaped patch antenna for GPS and IRNSS application. In: Proceedings of the 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT);25–27 May 2016; Ramanathapuram, India. pp. 179–183.
10. Hussein AH, Abdullah HH, Attia MA, Abada AM. S-Band compact microstrip full-duplex Tx/Rx patch antenna with high isolation. *IEEE Antennas and Wireless Propagation Letters* 2019; 18(10): 2090–2094.doi: 10.1109/LAWP.2019.2937769
11. Danh NT. A compact dual polarized ring slot loaded patch antenna for Navic applications. *National Journal of Antenna* 2020; 2(1). doi: 10.31838/NJAP/02.01.01
12. Vasanthan T, Vignesh V, Rajeswari MS, Dinesh M. Design of corner truncated microstrip square patch antenna for multi-constellation GNSS applications. In: Proceedings of International Academic Conference on Electrical, Electronics and Computer Engineering; Chennai, India. pp.68–70.
13. Praveen Chandran CR, Ramesh M, Raghavan S. Dual-band RHCP stacked microstrip antenna for IRNSS receiver. *International Journal of Pure and Applied Mathematics* 2018; 118(17): 47–59.
14. Lohar FL, Dhote C, Solunke Y, Suyan NK. Design of circularly polarized IRNSS receiver antenna using characteristic mode analysis. In: Proceedings of the 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT); 19–22 December 2019; Bangalore, India. pp. 1–5.
15. Khaleeq MM, Saadh AWM, Ali T, Reddy BS. A corner truncated circularly polarized antenna for IRNSS application. In: Proceedings of the 2017 International Conference on Smart Technologies for Smart Nation (Smart Tech Con); 17–19 August 2017; Bengaluru, India. pp. 148–152.
16. Mukherjee D, Sadhu NK, Chowdhury S, et al. Design of IRNSS/NavIC L5 band patch antenna. In: Proceedings of the National Conference on Materials Devices and Circuits in Communication Technology (MDCCT); 22–23 June 2018; Burdwan, India. pp. 92–95.
17. Birwal A, Singh S, Kanaujia BK. CPW-fed broadband slot antenna for GNSS and WiFi applications. In: Proceedings of the 2018 IEEE Indian Conference on Antennas and Propogation (InCAP); 16–19 December 2018; Hyderabad, India. pp. 1–4.

18. Kraanthi VS, Reddy BS, Sitaraman PV, et al. Circularly polarized dual band stacked patch antenna for satellite navigation applications. In: Proceedings of the 2018 IEEE Indian Conference on Antennas and Propogation (InCAP); 16–19 December 2018; Hyderabad, India. pp. 1–4.
19. Singh J, Lohar FL, Sohi BS. Design of circular polarized patch antenna for NaviC receiver applications. *IOP Conference Series: Materials Science and Engineering* 2021;1033(1):1–7.
20. Pourbagher M, Nourinia J, Ghobadi C. Circularly polarized printed crossed-dipole antenna using branch-line feed network for GPS applications. *AEU—International Journal of Electronics and Communications* 2020; 120: 153226.doi: 10.1016/j.aeue.2020.153226
21. Reddy BS, Kumar VS, Srinivasan VV, Mehta Y. Dual band circularly polarized microstrip antenna for IRNSS reference receiver. In: Proceedings of the 2015 IEEE MTT-S International Microwave and RF Conference (IMaRC); 10–12 December 2015;Hyderabad, India. pp. 279–282.
22. Patel Z, Sarvaiya A. Novel series fed dual band circular polarization antenna for navigational satellite system. *TELKOMNIKA Telecommunication Computing Electronics and Control*2022; 20(2): 252–259.doi: 10.12928/TELKOMNIKA.v20i2.23315
23. Shukla SB, Vidya KA, Chacko T, Mukundan KK. Single feed stacked circularly polarized patch antenna for dual band NavIC receiver of launch vehicles. In: Proceedings of the 2019 IEEE Indian Conference on Antennas and Propogation (InCAP);19–22 December 2019; Ahmedabad, India. pp. 1–5.
24. Zhang P, Wang H, Wang Y, et al. Investigations of compact tri-band antenna for CNSS application. In: Proceedings of the2013 Asia-Pacific Microwave Conference Proceedings (APMC);5–8 November 2013; Seoul, Korea (South). pp.1100–1102
25. Waqas M, Ahmed Z, Ihsan MB. Multiband Sierpinski fractal antenna. In: Proceedings of the 2009 IEEE 13th International Multitopic Conference; 14–15 December 2009; Islamabad, Pakistan. pp. 1–6.
26. Srivatsun G, Rani SS. A compact multiband fractal cantor antenna for wireless applications. *European Journal of Scientific Research* 2012; 71(2): 273–282.
27. Srivatsun G, Rani SS, Krishnan GS. A self-similar fractal cantor antenna for MICS band wireless applications. *Wireless Engineering and Technology* 2011; 2(2): 107–111. doi: 10.4236/wet.2011.22015
28. Anagnostou D, ChryssomallisMT, Lyke JC. Improved multiband performance with self-similar fractal antennas. In: Proceedings of IEEE Tropical Conference on Wireless Communication Technology; 15–17 October 2003; Honolulu, HI, USA. pp.271–272. doi: 10.1109/WCT.2003.1321520
29. Manimegalai B, Raju S, Abhaikumar V. A multifractal cantor antenna for multiband wireless applications. *IEEE Antennas and Wireless Propagation Letters* 2009; 8: 359–362.doi: 10.1109/LAWP.2008.2000828
30. Karthick M, Kashwan KR. Design of IRNSS receiver antennae for smart city applications in India. In: Proceedings of the 2015 Global Conference on Communication Technologies (GCCT);23–24 April 2015; Thuckalay, India. pp. 277–280.
31. Sada Siva Rao B, Raghavendra Vishnu T, Khan H, Ratnam DV. Spiral antenna array using RT-duroid substrate for Indian regional navigational satellite system. *International Journal of Soft Computing and Engineering* 2012; 2(2): 555–557.
32. Patel NJ, Sisodia AK. The review on tri-band microstrip antenna for GNSS applications.*Journal of Emerging Technologies and Innovative Research* 2015; 2(3): 472–476.
33. Bousselmi A, Gharsallah A, Vuong TP. A novel high-gain quad-band antenna with AMC metasurface for satellite positioning systems. *Engineering, Technology & Applied Science Research*2019; 9(5): 4581–4585. doi: 10.48084/etasr.2933
34. Ta SX, Chien DN, Nguyen KK, Ngoc HDT. Single-feed, compact, GPS patch antenna using metasurface. In: Proceedings of the 2017 International Conference on Advanced Technologies for Communications (ATC); 18–20 October 2017;Quy Nhon, Vietnam. pp. 60–63.
35. Garcia-Gamez L, Bernard L, Collardey S, et al. Compact GNSS metasurface-inspired cavity antennas.*IEEE Antennas and Wireless Propagation Letters* 2019; 18(12): 2652–2656.doi:10.1109/LAWP.2019.2947791
36. Liu S, Yang D, Pan J. A low-profile circularly polarized metasurface antenna with wide axial-ratio beamwidth. *IEEE Antennas and Wireless Propagation Letters* 2019; 18(7): 1438–1442.doi: 10.1109/LAWP.2019.2919533
37. Ali T,Biradar RC. Design of three metasurface acting as left-handed material for reconfigurable antenna. In: Proceedings of the 2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC); 15–17 December 2016; Chennai, India. pp. 1–6.
38. Li XS, Cheng LL, Liu XY, Liu QH. Wideband GNSS antenna covered by a double-sided metasurface. *AEU—International Journal of Electronics and Communications* 2018; 96: 170–177. doi: 10.1016/j.aeue.2018.09.032
39. Sumi M. Dual-band dual-rectangular-loop circular polarization metasurface antenna for GNSS receivers. In: Proceedings of the 2020 International Workshop on Antenna Technology (iWAT);25–28 February 2020; Bucharest, Romania. pp. 1–3.

40. Gaur A, Agrawal NK. The compact antenna using metamaterial EBG structure for eliminating mutual coupling between patch antenna. *Journal of Data Acquisition and Processing* 2023; 38(3): 1881–1887. doi: 10.5281/zenodo.98549409.
41. Gaur A, Agrawal NK. A hybrid coupler with a wide-band using modified schiffman phase shifter. *Journal of Optoelectronics Laser* 2023; 42(5): 1–6.
42. Gaur A, Agrawal N. A compact antenna with CPW feed for L, C, S and X band applications. In: Proceedings of the 2023 3rd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE) 2023. pp. 16–19.